# Interaction between colloidal spheres studied by optical tweezers

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光ピンセットは、強く集光したレーザーの光電場勾配を用いて、ミクロンサイズの粒子を捕捉する技術である。特に、レーザーの集光点を直線状に高速で往復運動させた場合、粒子はその走査方向に沿った１次元光ポテンシャル中に強く束縛される。本研究では、このような１次元光ポテンシャルを用いてシリカ粒子間に働く相互作用を直接測定した。

## 1 Introduction

Optical tweezer is a technique which enables us to trap micrometer-sized particles by the gradient force of a strongly focused laser beam. We can manipulate trapped particles easily by moving the focal point of the laser. Moreover, when the laser focus is scanned along a line with high frequency by a galvanometer mirror, a trapped particle diffuses freely along the scanning direction, while it is strongly confined in the perpendicular direction. This is called a line tweezers and enables us to measure the interactions between two colloidal spheres directly in various solutions (Figure 1)[1,2].

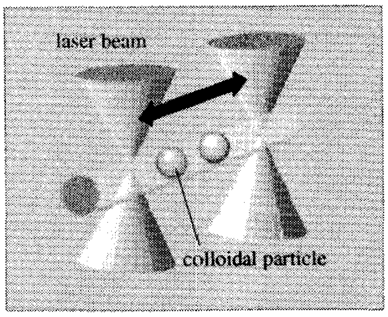


Figure 1: Two particles trapped in a line tweezers.

## 2 Characterization of a line tweezers

In advance of the measurement of interaction between collloids, we measured the potential profile of the line tweezers. Firstly, we trapped a silica sphere of 1 $\mu$m diameter and recorded its motion. Secondly, we located its position from each image and obtained the probability distribution of its position. The pobability $P(x)$ relates to the potential $U(x)$ through the Boltzmann distribution,

$$P(x) \propto \exp[-U(x)/k_\mathrm{B}T].$$

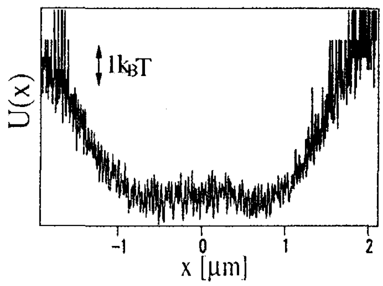


Figure 2: Potential profile of the line tweezers.

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Therefore we can determine the potential profile of the line tweezers from $P(x)$ (Figure 2).

## 3 Results and discussions

We measured the interaction potential $U(r)$ between two trapped silica spheres in the line tweezers. Two samples were used in our experiment. One is silica spheres of 1 $\mu$m diameter in aqueous solution. The other is silica spheres of 1 $\mu$m diameter in aqueous solution of polystyrene particles (PS) of 80 nm diameter (volume fraction of PS is 0.04). The measured interaction potential in aqueous solution and in aqueous solution of PS are respectively shown in Figures 3 and 4. The potential $U(r)$ are obtained by subtracting the line tweezers potential from the measured bare potential. Figure 3 indicates that $U(r)$ in aqueous solution is weakly attractive and repulsive for small $r$. Figurer 4 indicates that $U(r)$ is more attractive than one in Figure 3.

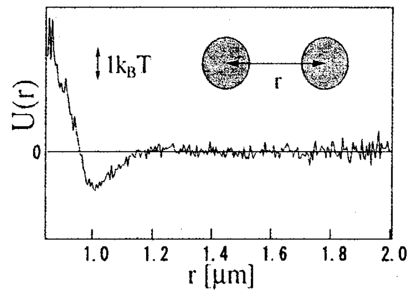


Figure 3: Interaction potential between two silica spheres $U(r)$ in aqueous solution.

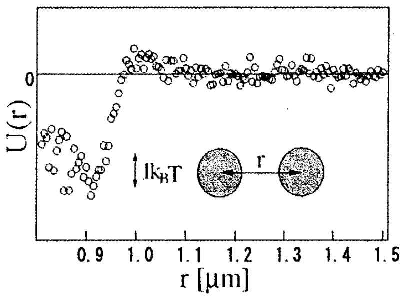


Figure 4: Interaction potential between two silica spheres $U(r)$ in aqueous solution of PS.

We attribute the attraction in Figure 4 to the depletion effect. In this case, there is a region called depletion zone, where the centers of the PS particles cannot penetrate, around each silica sphere. When two silica spheres approach, these regions overlap and the volume available to the PS increases (Figure 5). This decreases the total free energy of the system, and $U(r)$ is attractive. While when one polystyrene particle enters to the region between two silica spheres, it is repulsive.

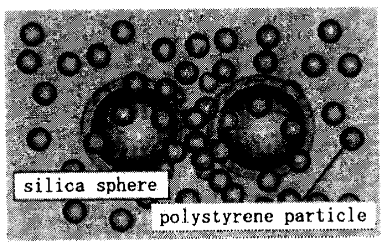


Figure 5: Depletion effect.

## References

[1] J.C. Crocker, J.A. Matteo, A.D. Dinsmore, and A.G. Yodh Phys. Rev. **82** (1999), 4352.

[2] Ritu Verma, J.C. Crocker, T.C. Lubensky, and A.G. Yodh Phys. Rev. **81** (1998), 4004.